RIPARIAN and FLOODPLAIN SCREEN ANALYSIS

OVERVIEW

This screen is divided into two analyses: riparian areas without significant floodplain areas (*Riparian Screen*), and riparian areas within floodplains (*Floodplain Screen*). The floodplain screen applies to streams falling within floodplain areas, as determined by FEMA floodplain maps, whereas the riparian screen applies only to streams not covered in the floodplain screen.

Each screen consists of 2 steps. Step 1 involves GIS analyses at a very coarse scale, summarizing how land use conditions have changed from historic conditions as a result of human influence, and inferring what this might indicate for riparian areas, summarized at the 6th field HUC. Step 2 involves random spot-checking throughout the Basin using aerial photos to see how well the coarse scale step predicts riparian condition in impaired and natural areas and to perform a screen at this finer scale using relationships of riparian functions with buffer width. Details are provided below.

PRODUCTS

For each screen, Riparian and Floodplain, across the Columbia River Basin:

- Map of percent of streams running through agricultural/urban land. Summarized as subwatersheds (6th field HUCs) having 0%, <25%, 25-50%, and >75% of streams or floodplains in agriculture/urban.
- Tables of summary data from aerial photo interpretation for each stratum (agriculture/urban, forest, shrub/grass), giving mean buffer widths, nearest vegetation type (type closest to the stream), and dominant vegetation type (dominant through 100m on each side) for left, right, and both stream banks.

APPROACH AND METHODS

Step 1: Coarse Scale Screen

For each test basin and across the entire Columbia River Basin, we summarized the percentage of streams that run through each of three categories of land cover, as follows: (a) agriculture/urban, (b) grass/shrub, and (c) forested/wetland. We then determined the percentage of current riparian areas that have likely been converted to agriculture/urban. For the Riparian Screen, we divided converted stream miles (e.g., streams running through the agriculture/urban habitat category) by total stream miles. Results for each were summarized by subwatershed (6th field HUC), and mapped (e.g., none, <25%, 25-50%, >75% converted). We hope to use a historic land use layer to verify our findings but the details are not yet worked out. For the Floodplain Screen, we divided converted floodplain area by total floodplain area in order to identify the amount of flooplain in every subwatershed that has been converted to agricultural land and other types. Specific methods for each screen are provided below.

Riparian Screen Methodology:

DATA INPUTS:

1) *Current Land Cover layer*

Current and historic wildlife habitat type layers are available for the entire Columbia River basin. These data have been created by the Northwest Habitat Institute in cooperation with the Fish and Wildlife 2000 Program of the Northwest Power and Conservation Council (NWPCC). Northwest Habitat Institute web site. 2003. (http://www.nwhi.org), Northwest Habitat Institute, Corvallis, OR. IBIS. 2003. Interactive Biodiversity Information System (http://ibis.nwhi.org), Northwest Habitat Institute, Corvallis, OR.

Current wildlife habitat types were derived from 1996 Landsat TM data, ancillary data (e.g., roads, streams, National Wetland inventory, other habitat inventories by local/state/federal agencies), and extensive field mapping. Specifically, the metadata and project report state:

This dataset seems to be the best available (finer scale than ICBEMP's Potential Vegetation groups, and coarser delineation of habitat types than USGS land use/land cover layer but without the shadowing problems of that layer). However, accuracies are highly variable and conclusions drawn from this layer might be suspect. Unfortunately, the historic layer is not at as high a resolution as the current layer, and no metadata are available.

2) *DEM-routed stream network*. Damon Holzer has created this network for the entire Columbia River Basin; it is more accurate than other available stream layers, and includes length and gradient of each reach.

3) *6th field HUC layer*. Boundaries of 6th field hydrologic units (USGS), used for summary purposes. Source: NWFSC Salmon Data Management Team (http://apps.nwfsc.noaa.gov/), Northwest Habitat Institute (http://www.nwhi.org/), or ICBEMP (http://www.icbemp.gov/).

STEPS:

1) Intersect stream layer with a 6th field HUC layer to assign 6th field HU codes to each stream segment for later summary.
2) Convert Northwest Habitat Institute (NWHI) layer grid to shapefile.
3) Intersect NWHI shapefile with stream layer and join attributes of NWHI layer to get category names.
4) Select stream sections having gradients between 1 and 20% to remove reaches that will be covered under the floodplain screen (<1%) and areas above the anadromous zone (>20%).
5) Summarize percent converted to agriculture/urban by 6th field HUC (see **Table 1** for example).
6) Map by 6th field HUC (see **Results Section**).

Table 1. Example of summary from step one (data entirely made-up).

HUC6	Stream reach	Stream length (m)	%Forested	%Grass-shrub	%Agric./urban	Length converted	%Converted
1	1	120	56	24	20	24	
1	2	657	12	59	29	190.53	
1	3	246	0	15	85	209.1	
1	4	123	45	0	55	67.65	
1	5	57	0	0	100	57	
summary		**1203**	**113**	**98**	**289**	**548.3**	**45.6**
2	1	168	9	68	23	38.64	
2	2	354	15	8	77	272.58	
2	3	387	19	75	6	23.22	
2	4	129	50	0	50	64.5	
2	5	456	20	0	80	364.8	
summary		**1494**	**113**	**151**	**236**	**763.7**	**51.1**

<ins>**Floodplain Screen Methodology:**</ins> (this screen developed and performed by Flo Damian)

Inputs:

HUC6 and HUC4 layers	ArcSDE on SDM4
Floodplain_WAORID_FEMA	ArcSDE on SDM4
LANDCOV_USGS raster layer	ArcSDE on SDM4
proportion_flood_change.cal field calculator expression	Provided by Flo

Outputs:

HUC6 personal geodatabase layer with attribute of proportion of floodplain that has changed from its natural state.

Steps:

1. Connect to ArcSDE on SDM4 as user NWFSC. Add the LANDCOV_USGS raster layer. Add the HUC6 layer.
2. Export the SDE.HUC6 polygons relevant to your sub-basin into a personal geodatabase. During the export process eliminate the unnecessary attributes but keep the SUBWAT as a unique identifier for later joins.
3. Set your analysis extent to your sub-basin scope and using the raster calculator clip the Landcov_USGS to create a smaller grid of land use.
4. Reclassify your new land-cover grid to have the following values changed to 1: 21, 22, 23, 31, 32, 33, 61, 81, 82, 83, 84, 85. Remove all the other values and change missing values to no-data. This operation will create a grid of all land types that have been changed by human activity.
5. Reclassify the land-cover grid to have value 11 changed to 1. Remove all other values and change missing values to no-data. This operation will create a grid of open water.
6. Add the Floodplain_WAORID_FEMA layer and select the features that overlap the HUC6 of your basin. Export these features to a subset layer

7. Add a field to your subset flood layer called flood100yr as small integer. Select all features with the ZONE attribute values of A, AE, AH, and AO. For your selection calculate this field to have a value of 1.
8. Dissolve the Floodplain layer on the flood100yr field. This should reduce the number of polygons and create a simpler layer.
9. Intersect this new floodplain layer with the HUC6 layer in order to transfer the SUBWAT attribute onto the floodplain polygons. Make sure to export to a geodatabase.
10. Summarize the area of your floodplain layer around the SUBWAT field to obtain a table with total floodplain area by huc.
11. Apply a zonal statistics procedure to the grid obtained at step 4 (the human changed land use). The zone dataset is the floodplain layer at step 9 with the zone field SUBWAT. Uncheck the chart statistics and output to a geodatabase table.
12. Apply a zonal statistics procedure to the grid obtained at step 5 (the open water). The zone dataset is the floodplain layer at step 9 with the zone field SUBWAT. Uncheck the chart statistics and output to a geodatabase table.
13. Add a field to the HUC 6 layer called flood_conv_prop (proportion of flood plain converted to other types) as double.
14. Join the three summary tables at steps 10, 11 and 12. Calculate the flood_conv_prop with the expression proportion_flood_change.cal. This represents the proportion of the floodplain in each HUC that got affected by human activity.

Step 2: Aerial Photos

We sampled aerial photos in agriculture/urban, forested, and grass/shrub areas (as classified by the Northwest Habitat Institute) throughout the Columbia River Basin to get an idea about what riparian buffers in each of these categories really look like. We began with the Grande Ronde as a test basin. We performed this step for both the Riparian Screen and the Floodplain Screen independently.

For each photo, we summarized average natural buffer widths for left, right, and both (average of right and left) stream banks. We also summarized the type of vegetation that most frequently occurred next to streams, and the dominant type of vegetation within a 100-m buffer on each side of the stream. The literature review appendix can be used for interpretation of functions commonly associated with types of riparian buffers, and the level of function at different buffer widths. Based on bootstrap analysis of preliminary data in the test basin, we determined that 20 photos in agricultural areas and 10 each in forested and shrub/grass areas allowed us to estimate the mean buffer width with a precision of less than +/-15%. Thus for the Columbia Basin, we decided to sample at least 50 photos in agriculture/urban areas, and at least 25 photos in each of the natural areas (forested and shrub/grass). Post-hoc bootstrap analyses suggested that these sample sizes were sufficient for confidence limits well below +/-10%. Additionally, we performed some calibration of aerial photo interpretation by driving to sites and visually assessing what we saw. Future additional aerial photo samples and further ground-truthing should only increase our accuracy.

Data sources:

1) Aerial photos (1m accuracy) from TerraServer, size of photo downloaded was approximately 600m to a side (36000m^2 in area)

2) DEM-routed stream network with gradients <20%
3) NWHI institute land cover layer
4) Floodplain layer

Process:

1) Develop a sampling design for where to pick points to download aerial photos, and decide on how big a sample point map should be.
    a. Develop sampling grid layer (resolution 600m to a side for test basin and 7000m to a side for the Columbia Basin)
    b. Intersect grid layer with stream network to remove any grid cells with no stream running through them, and number grid cells.
    c. Based on random number generator (in Excel), create list of random grid cells to sample from.
    d. Stratify grid into agriculture/urban, forested, and grass/shrub categories.
2) Get random grid cell ID, locate suitable area to sample, and download aerial photo to use.
    a. Choose area to sample based on these criteria:
        i. For the Riparian Screen, a suitable area within the random grid cell to sample has to be entirely (or nearly all) within a habitat type stratum, have at least 500 linear meters of anadromous-accessible stream, and the sample cannot be within a floodplain area.
        ii. For the Floodplain Screen, in addition to the first two of the above criteria, areas sampled have to fall within areas where the floodplain is >2 times the stream width.
    b. Zoom to chosen grid cell and download aerial photo.
        i. Ensure that there are really 500m of stream (since routed network often does not match stream in photo).
        ii. Ensure that the photo is readable (i.e., not bleached out or too highly shadowed).
    c. If one of these conditions is not met, move to next random grid cell and try again.
    d. Based on bootstrap analysis (see below), for each analysis (floodplain and riparian), we sampled at least 50 points in the agriculture/urban stratum, and at least 25 each in forested and grass/shrub strata.
3) Identify stream, sample boundary buffer, and transect locations (see **Figure 1**).
    a. Trace 500 linear meters of stream with line tool.
    b. Create 5 transect points along the line, approximately 100m apart (turn off photo layer while assigning points to avoid bias). Based on sample size analysis, 5 transects per photo gave nearly identical results as 10 transects per photo (see below).
    c. Create 100m buffer around line; we will sample only land classification types within this buffer along transects.
4) Assess amount of left and right buffers falling into several natural land cover categories (see **Table 2**).
    a. Measure distance from stream (m) of natural buffers along the left and right banks that fall into the following land cover categories: forested, shrub, mixed (shrub & trees), grass, and other natural (e.g., cliff, rock, gravel). Record type of buffer up to 100m on each side but stop measurement of buffer widths when a disturbed

land type is reached (e.g., agriculture, road, urban). Record as specifically as possible the type of disturbance (e.g., row crops, pasture, small grains). Where photos are difficult to interpret (e.g., shadow problems), make best guess and record rationale in comments section.

b. Be as specific as possible (even if we end up lumping we'll have the data if we want to come back to it), and note difficult decisions in the comments column of the datasheet.
c. Assess the type of NWHI data underlying stream at each transect.
d. In addition, record evidence of hydromodification (e.g., levees/dikes, channelization), channel incision, relict channels, and channel pattern (e.g., straight, meandering, braided, island braided) for the floodplain screen.

5) Calculate summary information that can be used to identify buffer widths and nearest and dominant vegetation types in each stratum (agriculture/urban, forested, shrub/grass) for interpretation of coarse screen.

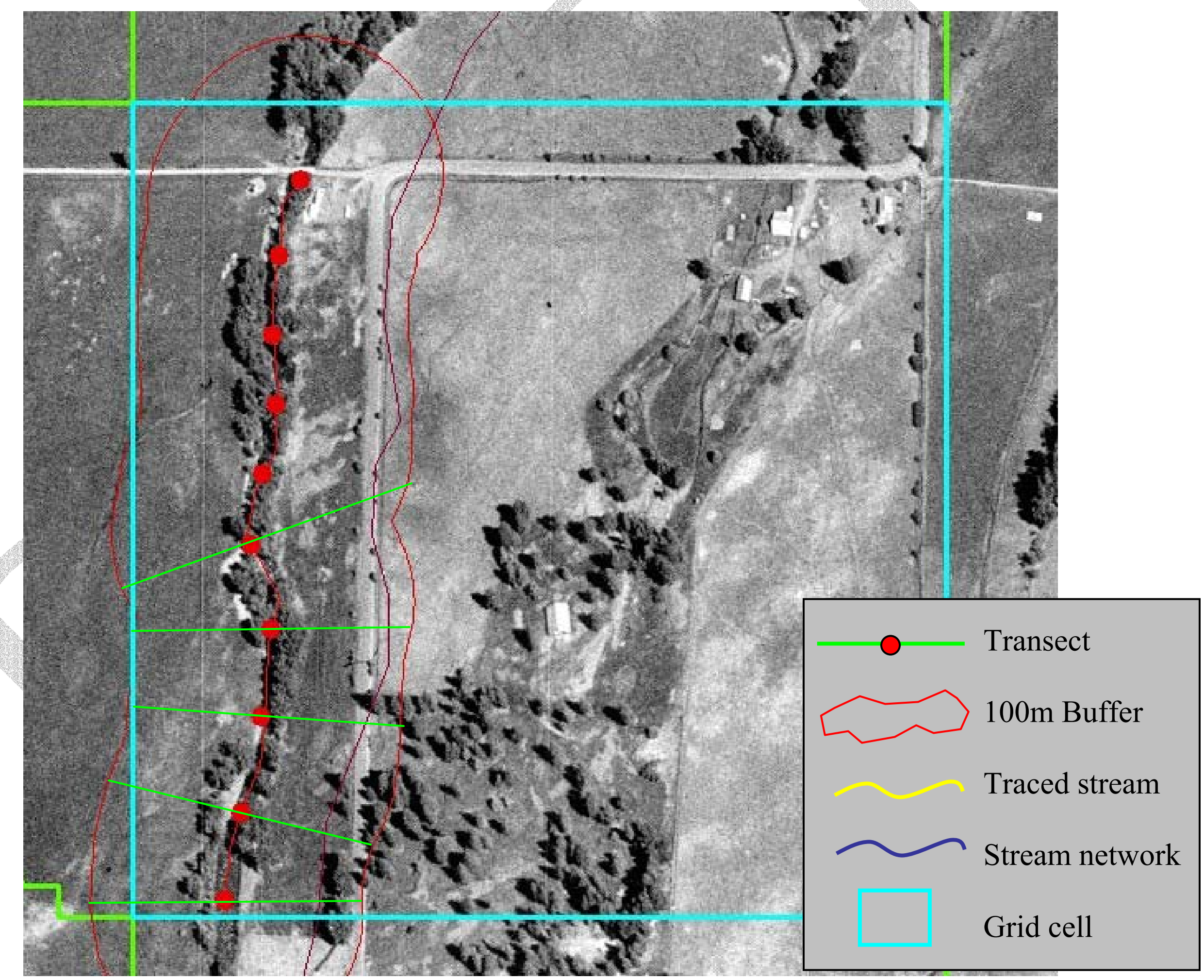


Figure 1. An example of an aerial photo and sampling transects in an agricultural area in the Grande Ronde basin.

Table 2. Example datasheet and analysis for three aerial photos. We include up to 4 categories (only 2 shown here for example). NWHI = vegetation code used in the Northwest Habitat Institute data layer. "End" refers to any unnatural habitat run into within the 100m transect (e.g., agriculture, urban, road).

		aerial photo L					aerial photo R						
Grid ID	**Transect**	**category1**	**dist1 (m)**	**category2**	**dist2 (m)**	**end**	**category**	**dist1 (m)**	**category2**	**dist2 (m)**	**end**	**NWHI**	**Comments**
18449	1	mixed	100				forest	21	shrub	79		15	
	2	forest	30	mixed	70		forest	64	mixed	36			
	3	mixed	47	grass	53		forest	37	grass	63			
	4	mixed	43	forest	57		mixed	65	grass	35			
	5	mixed	100				forest	29	grass	71			few trees @ edge
	6	forest	100				forest	47	grass	53			
	7	mixed	100				forest	43	grass	57			
	8	forest	35	mixed	65		forest	39	grass	61			
	9	forest	58	grass	42		forest	68	shrub	32			
	10	forest	100				forest	48	shrub	52			
24116	1	mixed	30			road	forest	20	mixed	80		5	highly shadowed
	2	mixed	26			road	forest	29	mixed	71			
	3	shrub	30			road	mixed	33	shrub	67			
	4	mixed	36			road	mixed	36	shrub	64			
	5	mixed	29	grass	8	road	forest	30	shrub	70			
	6	forest	29	grass	15	road	mixed	27	grass	63			
	7	forest	12	grass	32	road	forest	22	mixed	78			
	8	mixed	21			road	mixed	13	shrub	87			
	9	mixed	9			road	forest	19	shrub	81			included rock in road (RB)
	10	grass	26			road	forest	21	mixed	79			
21626	1	mixed	100				mixed	100				7	
	2	mixed	100				mixed	100					
	3	grass	46	mixed	54		mixed	100					
	4	mixed	100				forest	100					
	5	mixed	100				mixed	100					
	6	mixed	100				shrub	100					
	7	mixed	100				shrub	53	grass	47			
	8	forest	100				shrub	50	grass	50			
	9	forest	100				shrub	44	grass	66			
	10	forest	100				mixed	100					

Analyses to Determine Sample Size

Using the Grand Ronde test basin dataset, we performed some analyses to determine (1) how many transects we need to sample per photo, and (2) how many photos to sample per stratum (agriculture, forested, and shrub/grass).

Number of Transects Per Photo

We summarized the data for the Grande Ronde using both 10 and 5 transects per photo. To drop half of the transects, we omitted data from every other transect such that data included only transects 1, 3, 5, 7, and 9. We then compared summaries for both banks from this dataset having only 5 transects per photo to summaries for both banks from the original dataset having 10 transects per photo. We compared mean buffer widths with paired t-tests, and nearest and dominant vegetation types with 1-way ANOVAs. Results were nearly identical (**Table 3**), thus we reduced the number of transects sampled per photo for photo interpretation of the Columbia River Basin dataset.

Table 3. Summary of comparisons of data analyzed with 10 and 5 transects per photo, and the corresponding p-value for each test (α=0.05). For nearest and dominant vegetation categories, numbers shown represent the number of occurrences in each of the following categories, respectively: forest, mixed, shrub, grass, other, and none.

Stratum	**Summary data compared**	**10 transects**	**5 transects**	**P-value**
Agriculture	Mean buffer width (SD)	47.3 (33.4)	47.0 (34.2)	0.9806
	Nearest vegetation	3,2,2,8,1,4	3,2,3,7,1,4	1.00
	Dominant vegetation	3,2,1,9,1,4	3,2,1,9,1,4	1.00
Forested	Mean buffer width (SD)	86.5 (20.1)	87.1 (18.6)	0.9505
	Nearest vegetation	4,5,0,0,1,0	4,5,0,0,1,0	1.00
	Dominant vegetation	4,5,0,0,1,0	5,5,0,0,0,1	1.00
Shrub/Grass	Mean buffer width (SD)	83.6 (19.3)	82.7 (20.6)	0.9154
	Nearest vegetation	4,1,1,4,0,0	3,2,1,4,0,0	1.00
	Dominant vegetation	2,2,3,3,0,0	2,1,3,4,0,0	1.00

Number of Photos per Stratum

To determine how many photos we should sample in each stratum, we performed a bootstrap analysis on mean buffer width using data for both banks (mean of left and right buffer widths). We began with the agriculture/urban stratum dataset, which was based on interpretation of 20 aerial photos. The bootstrap analysis consisted of several steps. First, we drew 20 samples randomly from our dataset, with replacement. Then we calculated the average of the first two samples, the first three samples, and so on until all 20 samples were included. An example of the cumulative mean and confidence intervals plotted against sample size from one randomly drawn dataset is shown in **Figure 2A**. Next, we randomly drew another 20 samples and calculated the cumulative average for that dataset. We performed the bootstrapping 1000 times, and calculated 95% confidence intervals for the entire dataset (**Figure 2B**). The 95% confidence interval (at α=0.05) shrinks to around +/- 14% at a sample size of 20. Thus, we can assume that with 20 photos in the agriculture/urban stratum, the true mean buffer width lies somewhere between 33.3 and 61.9 m. We performed a similar analysis for the forested and shrub/grass strata as well (**Figure 3A** and **3B**, respectively). Although we analyzed only 10 photos for each of these strata, the results are similar to those for the agricultural stratum, indicating that we can analyze less photos for estimating buffer widths in these strata and still have similar confidence, likely because the agriculture/urban data were more variable.

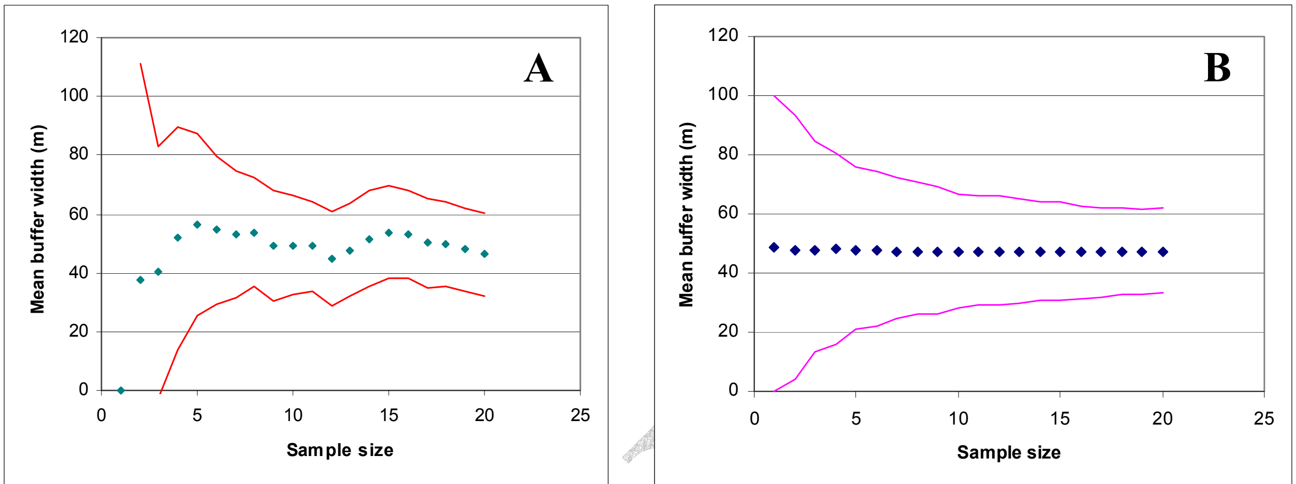


Figure 2. Cumulative mean and confidence intervals plotted against sample size from one randomly drawn dataset (A), and for all 1000 bootstrapped data (B).

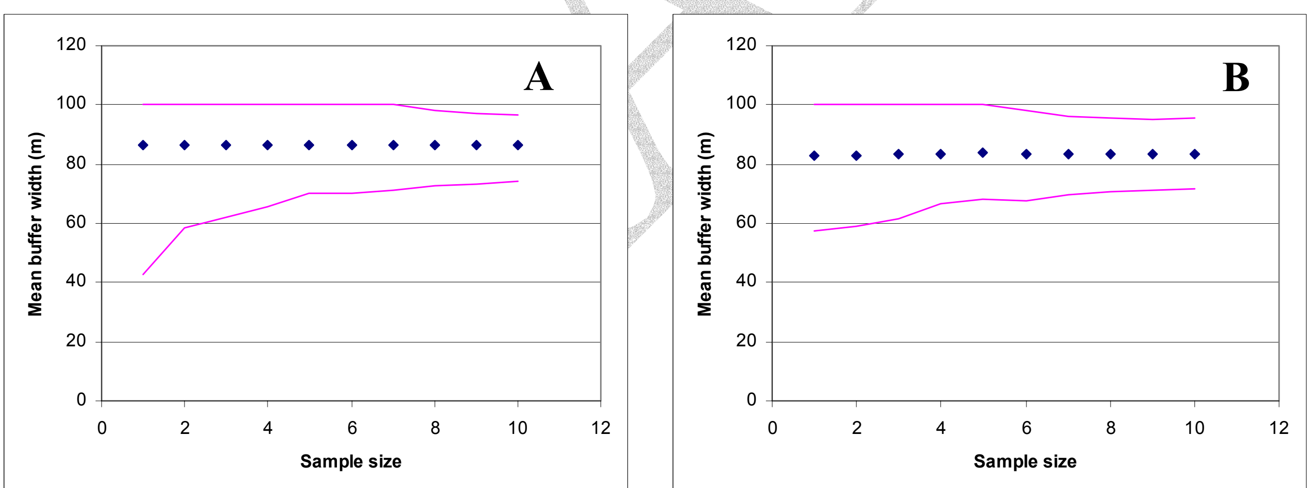


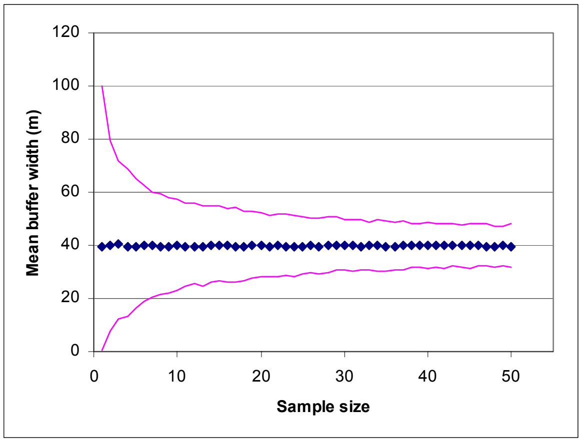
Figure 3. Cumulative mean and confidence intervals of bootstrapped data for the forested stratum (A), and the shrub/grass stratum (B).

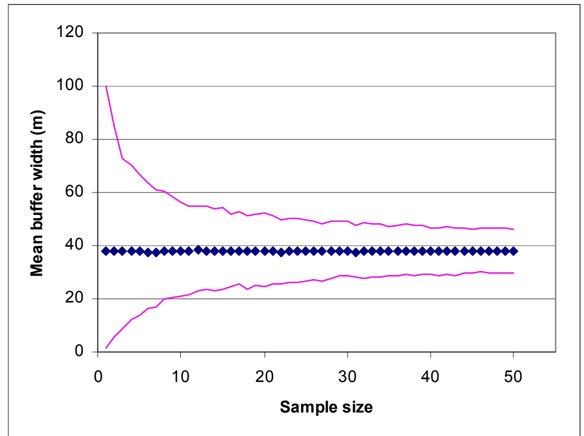
__**Columbia River Basin Dataset**__

Based on results from the Grande Ronde test basin, we sampled 50 photos in the agriculture/urban habitat stratum, 25 in the forested, and 25 in the shrub/grass stratum for both the riparian and floodplain screens. Post-hoc bootstrap analyses of these datasets indicate that our confidence intervals should be around +/-10% in all cases (**Figure 4**).

RIPARIAN SCREEN	FLOODPLAIN SCREEN

Agriculture/urban Stratum

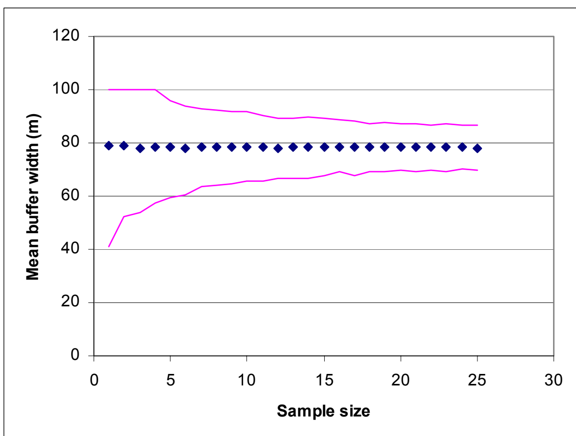


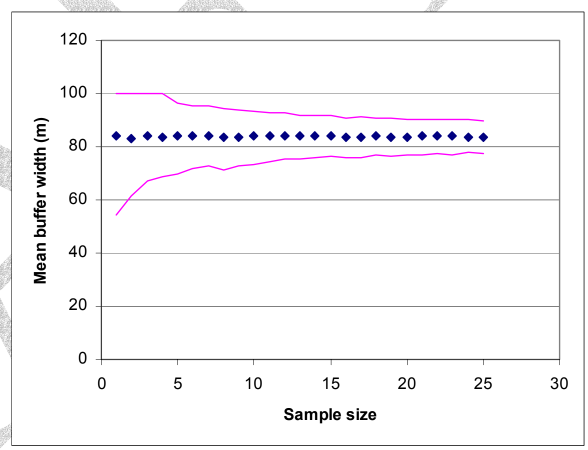


mean = 39.8, ci = +8.4/-7.8, n=50

mean = 37.9, ci = +8.1/-8.2, n=50

Forested Stratum

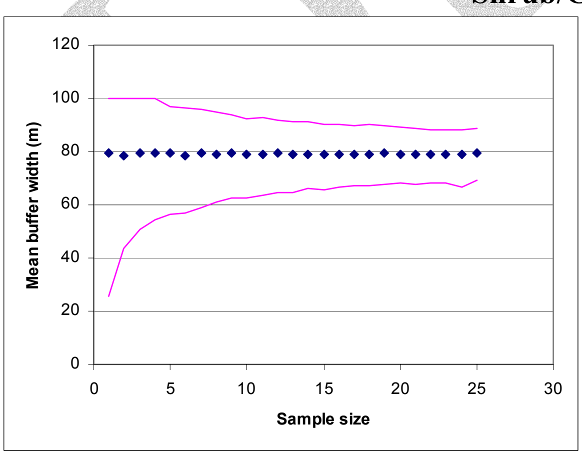


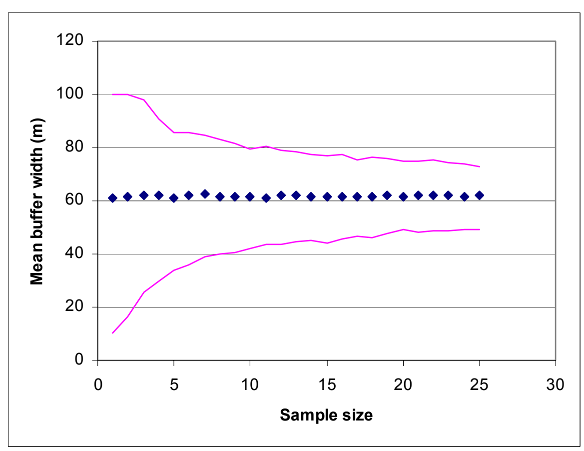


mean = 78.4, ci = +8.4/-8.6, n=25

mean = 83.9, ci = +5.9/-6.1, n=25

Shrub/Grass Stratum





mean = 79.1, ci = +9.3/-10.2, n=25

mean = 61.7, ci = +11.0/-12.4, n=25

Figure 4. Bootstrap analyses for aerial photos throughout the Columbia River Basin.

Results

Coarse Screen

Coarse screen summary maps for the Riparian Screen in the Grande Ronde and Yakima test basins are shown in **Figures 5** and **6**, respectively. Coarse screen analyses for the Floodplain Screen in the test basins and the Riparian and Floodplain screens in the Columbia River Basin are not yet complete.

Aerial Photos

Results of aerial photo interpretation for the riparian and floodplain screens are summarized in **Table 4**. Refer back to **Table 3** for a summary of Grande Ronde basin data. More detailed summaries and raw data from aerial photo interpretation are available upon request.

NOTE: Buffer widths shown here were calculated on data classified by NWHI habitat type strata and are thus likely to have misclassification errors (e.g., there were many cases where the habitat layer said an area should be agriculture and it was really 100% shrub-steppe, and vice versa). In the near future, we will create a misclassification tree and analyze buffer width stratified by dominant habitat type as obtained from aerial photos for a more realistic interpretation of buffer width in each of the habitat type strata.

Table 4. Summary of aerial photo analyses in the Columbia River Basin. Habitat classification is based on NWHI data layer. Frequency of photos having a given vegetation type nearest the stream ("near") or dominant vegetation type within the 100m buffer ("dom").

A. Non-Floodplain Areas						
	agriculture/urban		**forested**		**shrub/grass**	
buffer width						
n	57		32		25	
mean	39.5		82.3		79.1	
stdev	28.6		20.2		25.1	
vegetation type						
	near	*dom*	*near*	*dom*	*near*	*dom*
forest	23	17	19	17	5	4
mixed	7	7	9	9	3	1
shrub	11	11	2	5	12	12
grass	6	12	2	1	4	7
other	0	0	0	0	0	0
none	10	10	0	0	1	1

B. Floodplain Areas						
	agriculture/urban		**forested**		**shrub/grass**	
buffer width						
n	56		32		25	
mean	39.4		83.3		61.7	
stdev	30.0		20.5		32.2	
vegetation type						
	near	*dom*	*near*	*dom*	*near*	*dom*
forest	15	18	11	12	2	1
mixed	16	14	11	10	4	4
shrub	14	12	8	7	13	13
grass	8	7	2	3	5	5
other	1	0	0	0	0	0
none	2	5	0	0	2	2

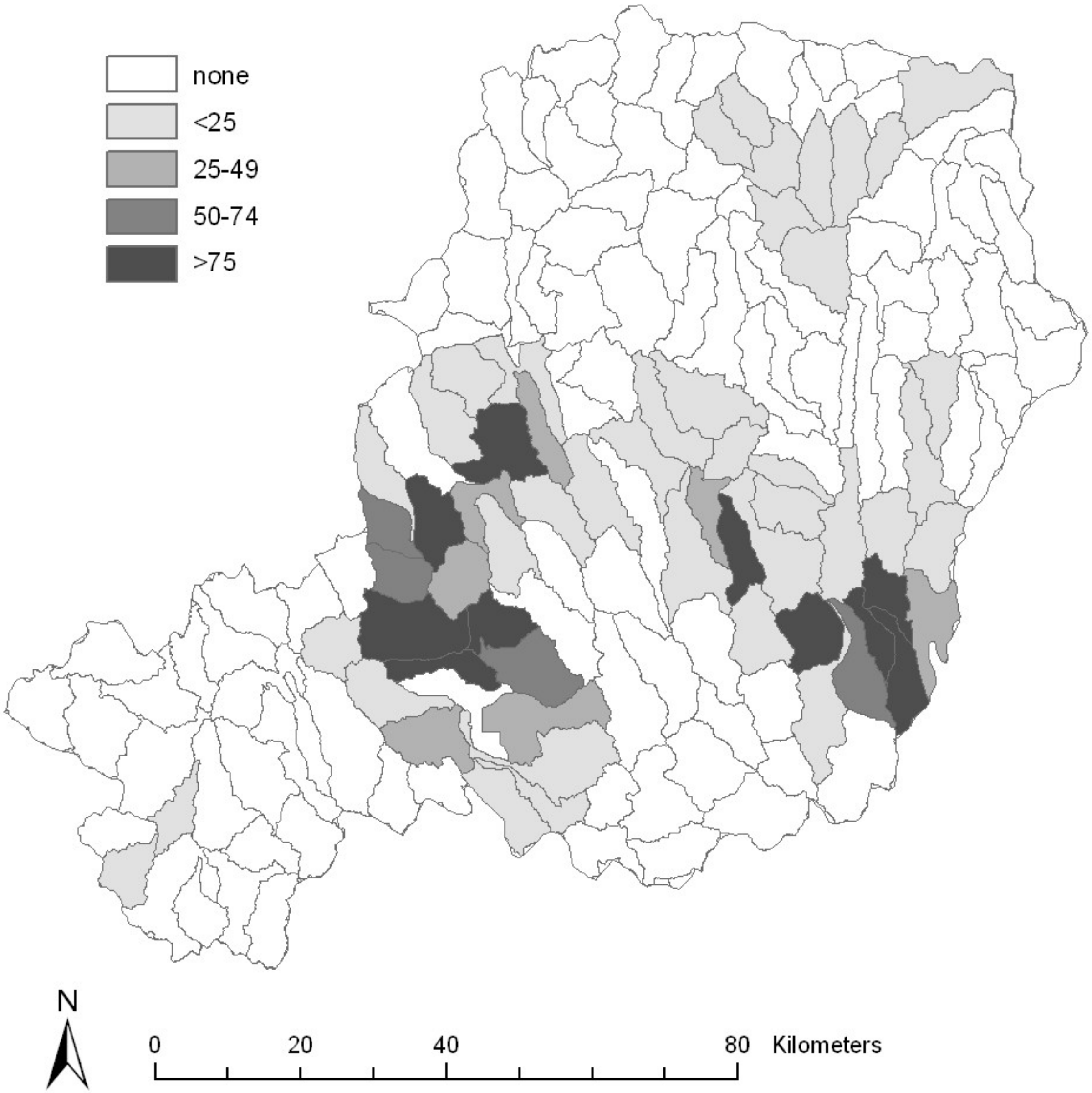


Figure 5. Percent of streams in the Grande Ronde basin running through areas classified by the Northwest Habitat Institute layer as agriculture/urban (codes 19 an 20), summarized by 6th field HUCs.

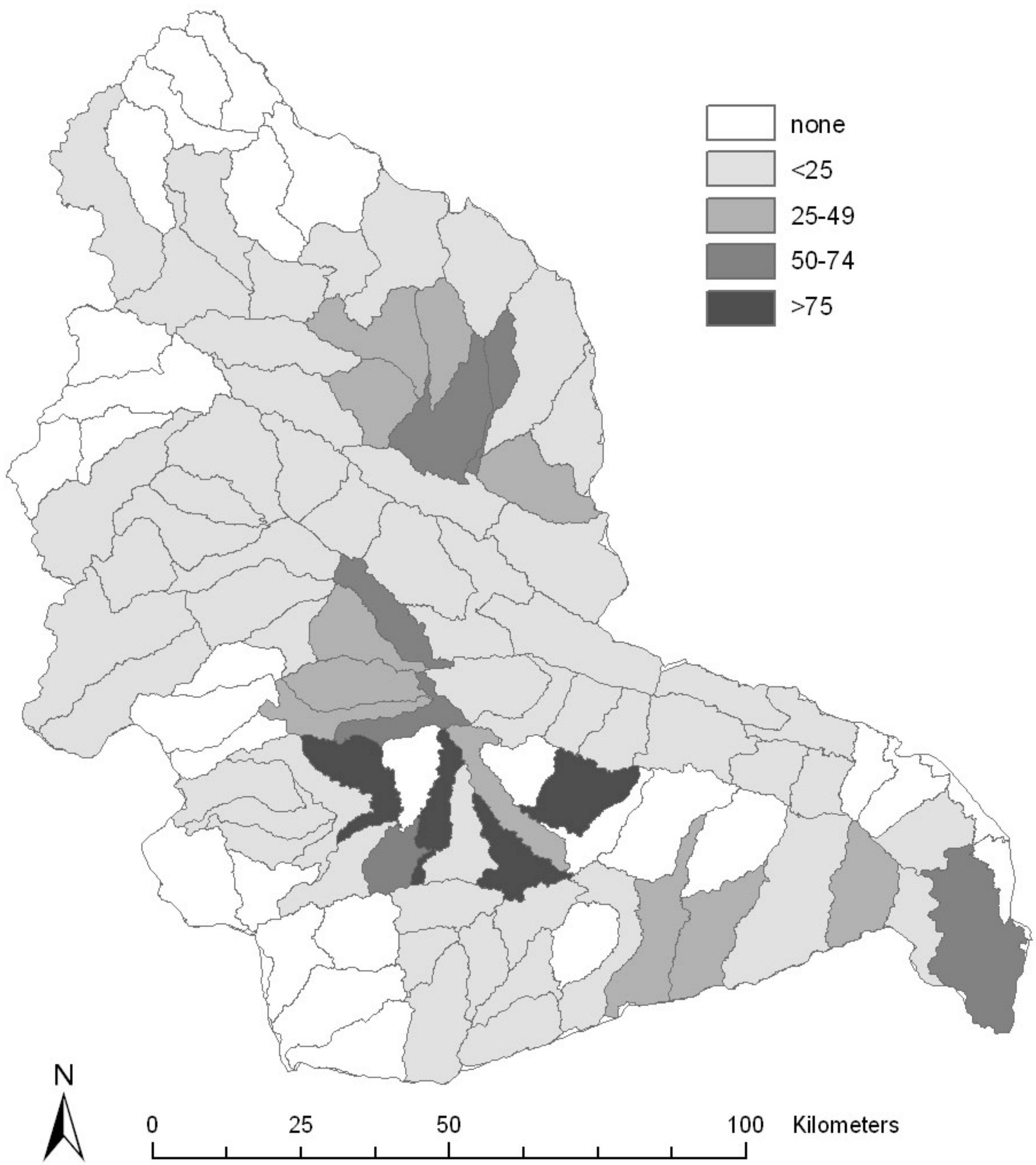


Figure 6. Percent of streams in the Yakima basin running through areas classified by the Northwest Habitat Institute layer as agriculture/urban (codes 19 and 20), summarized by 6th field HUCs.

APPENDIX. RIPARIAN FUNCTIONS IN THE COLUMBIA RIVER BASIN

Riparian areas provide many functions that contribute to habitat that is suitable for viability of salmonids, as well as the integrity of the stream network itself (Table 1).

Table 1. Possible functions of riparian vegetation. Importance of each function may differ among regions.

General Category	Specific Riparian Function
Bank Stability/ Channel morphology	Stabilize stream banks (root strength)
	Help sustain natural channel morphology (prevent channel widening or incision)
	Contribute to habitat complexity (undercut banks, percent pools)
Temperature Control	Maintain stable temperature regime
	Decreased stream temperatures via shading
Organic Matter Supply/Habitat complexity	Provide large woody debris cover
	Provide organic carbon and nutrients to support the aquatic food web
Filtering Capacity	Filter sediment input
	Reduce pollutants and filter runoff, including nutrients (N & P)
	Improve air quality and lower ozone levels
Hydrology Related	Help reduce the severity of floods; maintain stable water flows
	Increase channel-floodplain connections (facilitate exchange of ground- and surface-water)
Other Functions	Provide critical wildlife habitat

Forested Areas

For forested areas west of the Cascades, bank stability (e.g., root strength), organic matter input (e.g., large woody debris and litter fall), and stream temperature control (e.g., shading) have been considered important riparian functions driving stream condition. FEMAT (1993) related these functions to buffer widths in terms of site potential tree heights, but this has also been represented in terms of buffer width (Beechie et al. 2003; Figure 1). A similar set of curves can be drawn for the same functions in eastern Washington, based on an adjustment in average site potential tree height between eastern and western Washington (Figure 2). We will use this set of curves for forested areas of the Interior Columbia, in the absence of any better data.

We will use the curve for large woody debris input to determine percent riparian function at a given buffer width in forested areas, since that is the function requiring the widest buffer for complete functionality.

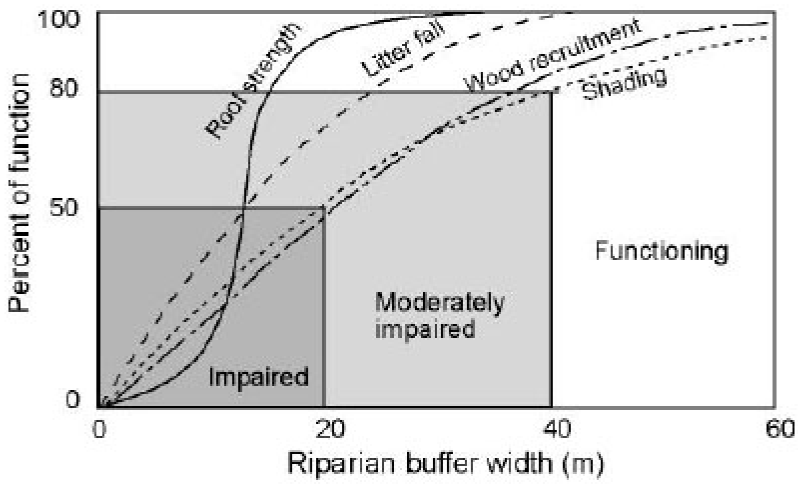


Figure 1. Percent function for four riparian functions important in forested areas west of the Cascades; reproduced from Beechie et al. 2003; caption reads "Illustration of change in riparian function with distance from channel (curves adapted from Sedell et al. 1997), and the Skagit Watershed Council's classification of impaired, moderately impaired, and functioning riparian forests."

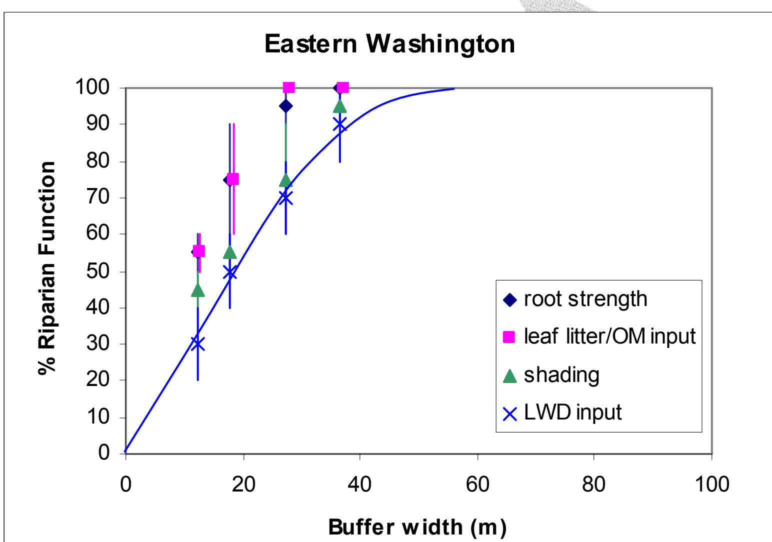


Figure 2. Percent function for the same four riparian functions as in Figure 1, but modified for eastern Washington, based on site potential tree height (west = 175 ft, east=125 ft). Data are from a table on NOAA Fisheries Northwest Region's website (www.nwr.noaa.gov/1salmon/salmesa/4ddocs/4dws4c.htm), but no citations are provided. The curve is drawn for large woody debris (LWD) input, because it is the function requiring the widest buffers for complete functionality.

Non-forested Areas

For non-forested areas of the Interior Columbia River Basin (e.g., shrub-steppe, grasslands), we developed functional relationship curves similar to those developed for forested areas. We decided that two of the functions important in western forested areas were also important here: bank stability (e.g., root strength), and stream temperature control (e.g., shading). However, large woody debris input is unlikely to be important but filtration of sediment, nutrients, and pollutants from runoff is likely to be highly important in non-forested areas of the Interior. Our curves are based on data from a literature review of the relationship of several riparian functions with buffer width. These are discussed below.

Filtration— Figure 3 shows the relationship of percent sediment removal vs. buffer width in primarily non-forested riparian buffers. Nitrogen and phosphorus (in their various forms) removal functions appeared similar (Figure 4), and because phosphorus often sticks to sediment particles, we reasoned that the relationship for sediment removal would be a good surrogate for filtration in general. Filtration capability by riparian buffers decreases with increasing slope. Four of the 5 data points not shown in Figure 4 because they exceeded 100m in width were for hillslopes >7%.

Temperature control— Figure 5 shows the relationship of percent shading vs. buffer width, based on the studies we consulted.

Bank stability— Our review of the literature on root strength, a surrogate for bank stability, did not allow comparison with riparian buffer widths. However, we did surmise that fine root biomass and root strength of wetland vegetation (e.g., sedges, rushes) and grasses is greater than that of trees, and that of trees is greater than that of agricultural plants. Denser roots are stronger at resisting compression, such as might occur during access of cattle to a stream. Root strength also decreases with depth, thus root strength is much lower in incised areas as compared to natural areas. Based on this information, we chose to use the curve for root strength for forested areas (Figure 2), reasoning that it would be a conservative estimate for non-forested areas.

Overlaying the threshold curves for these three functions indicates that sediment filtration is the function requiring the widest riparian buffer for complete functionality. Thus, we will use this curve to determine percent riparian function at a given buffer width for non-forested areas.

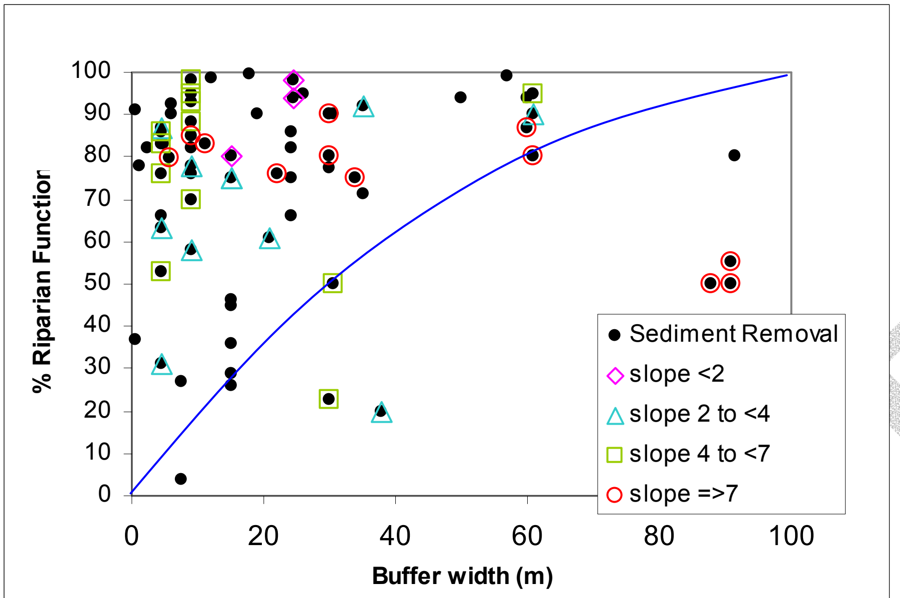


Figure 3. Percent of sediment removal vs. buffer width, based on 80 data points from 39 studies; 3 of these studies included data for forested riparian buffers and 37 included data for presumably non-forested (e.g., grass, shrub, or type not reported) riparian buffers. Only data reported for 100m buffer widths or less is included (5 points fell beyond). Colored symbols separate studies by percent hillslopes of riparian areas, where data were provided in original studies. Sediment forms varied (e.g., total suspended solids, fine sediment), and all forms are included here. **The blue line represents a threshold above which 90% of the data points fall.**

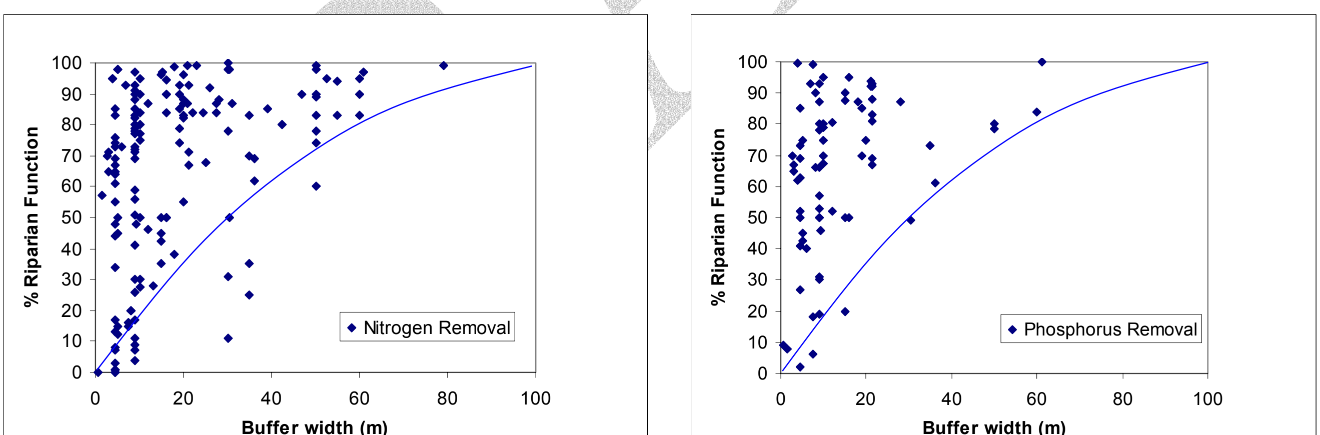


Figure 4. Percent removal of nitrogen (left panel) and phosphorus (right panel) in relation to riparian buffer width. The blue line is the same threshold as derived for sediment removal (Figure 3), overlain for comparison. Data are from 53 and 29 published studies for nitrogen and phosphorus, respectively. Note that 5 and 7 data points, respectively, fell below zero (indicating increases rather than decreases in nutrient amounts); these data points occurred in buffers <10m wide.

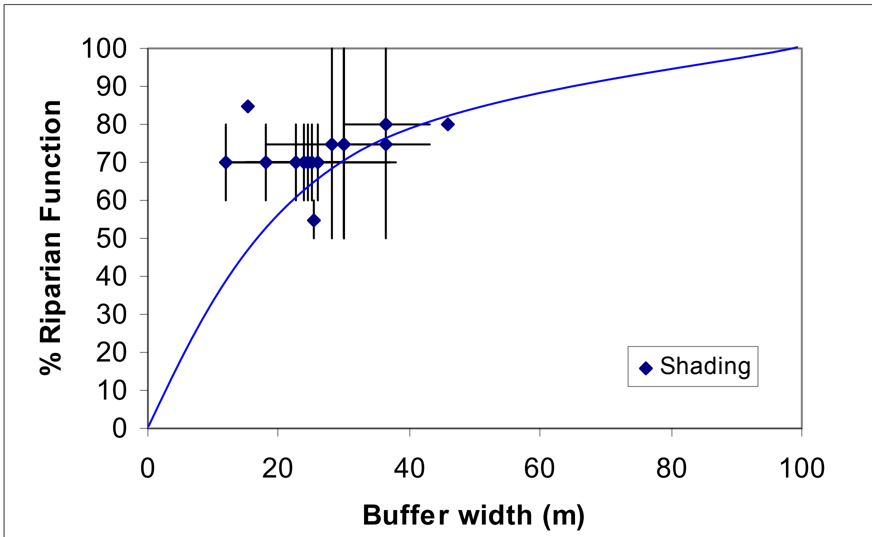


Figure 5. The relationship of percent shading to riparian buffer widths, as reported in 15 published studies. Most studies reported ranges, rather than mean values. Error bars, when present, are ranges of values reported in each study, and points indicate means. No information is available on type of vegetation in buffers reported here. The blue line represents a threshold above which 90% of the data points fall.

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